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In re Patent Application of: Tomasz J. Cholewo et al.
Title: METHOD AND APPARATUS FOR EXPANDING A COLOR GAMUT
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METHOD AND APPARATUS FOR EXPANDING A COLOR GAMUT

Field of the Invention

This invention relates to color printing, and more particularly, to the use of colorants and gamut scaling in color printing.

Background of the Invention

Combinations of the colorants cyan, magenta, and yellow (CMY) are capable of producing images containing colors in the visible spectrum, so many color imaging systems are designed around CMY colorants. To improve image quality and to reduce the costs of printing, black is sometimes added to a CMY color gamut to form a CMYK (cyan, magenta, yellow, and black) color gamut. The visual details of an image rendered from a CMYK color gamut are sharper than the visual details of the same image rendered from a CMY color gamut. Similarly, the gray balance of an image rendered from a CMYK color gamut is better than the gray balance of an image rendered from a CMY color gamut. So, many modern color imaging systems utilize the colorants cyan, magenta, yellow, and black (CMYK) in forming color images.

Most conversion methods from CMY to CMYK simultaneously add black colorant and reduce the amounts of cyan, magenta, and yellow. One popular solution is based on a combination of Under Color Removal (UCR) and Black Generation (BG) functions:

$$\begin{aligned} PK &= \min(C, M, Y) \\ C_1 &= C - UCR(PK) \\ M_1 &= M - UCR(PK) \\ Y_1 &= Y - UCR(PK) \\ K_1 &= BG(PK) \end{aligned} \qquad (1)$$

where (C, M, Y) are input values and (C_1, M_1, Y_1, K_1) are the output values. The black generation function computes the black colorant amount based on the process black amount P. The CMY values are reduced by an amount dependent on PK. However, such

a simple transformation does not preserve colorimetric relations and does not allow use of the whole printer gamut.

Unfortunately, even though each of these processes show improved gray balance in images rendered from a CMYK color space when compared with images rendered from a CMY color space, each of these processes also has some disadvantages. One disadvantage is that the UCR and GCR processes are not based on human visual perception and therefore fail to faithfully reproduce the original image. A second disadvantage of most CMYK systems is that they fail to utilize the entire gamut of the CMYK color space. Failing to utilize the entire gamut results in a suboptimal rendering of a CMY image in a CMYK color space.

For these and other reasons there is a need for the present invention.

Summary of the Invention

The above mentioned problems with generating a CMYK color gamut from a CMY color gamut are addressed by the present invention, which will be understood by reading and studying the following specification.

In one embodiment, a gamut in a first color space is converted to a gamut in a second color space. The gamut in the second color space is converted to a gamut in a third color space. A lightness component of a gamut value in the third color space is rescaled to form a modified gamut. Finally, the modified gamut is converted to a second gamut in the second color space. In an alternate embodiment, rescaling a lightness component of a gamut value in the third color space to form a modified gamut comprises modifying the gamut in the third color space by changing a lightness component of the gamut value in the third color space such that an upper surface of the gamut in the first color space is preserved and a lower surface of the gamut in the first color space is mapped to a bottom surface of the gamut of the second color space to form an expanded gamut in the third color space.

In another embodiment, a gamut in a CMY color space having an upper surface and a lower surface is converted to a gamut in a CMYK color space having a bottom surface. The gamut in the CMYK color space is converted to a gamut in a CIELAB color

space and the gamut in the CIELAB color space has a lightness component. The gamut in the CIELAB color space is modified by changing the lightness component such that the upper surface of the gamut in the CMY color space is preserved and the lower surface in the CMY color space is mapped to the bottom surface of the gamut of the CMYK color space to form a gamut in an expanded CIELAB color space. Finally, the gamut in the expanded CIELAB color space is transformed to form a second gamut in the CMYK color space. In an alternate embodiment, a CIELAB gamut having an L* component is modified to form a modified CIELAB gamut, and the modified CIELAB gamut is converted to a color control space gamut subject to K constraints and Total Area Coverage (TAC) constraints. In another alternate embodiment, the CIELAB gamut is modified to form a modified CIELAB gamut and the method comprises linearly rescaling the L* component of the CIELAB gamut to form the modified CIELAB gamut.

In another embodiment, a method comprises obtaining a CIELAB space gamut from a CMYK space gamut obtained from a CMY space gamut, expanding the CIELAB space gamut by changing the lightness component of the CIELAB space gamut, and transforming the CIELAB space gamut into a second CMYK space gamut. In an alternate embodiment, changing the lightness component of the CIELAB space gamut comprises linearly rescaling the lightness component of the CIELAB space gamut. In another alternate embodiment, linearly rescaling the lightness component in the CIELAB space gamut comprises computing a rescaling factor that is a function of an L_{min}, an L_{max}, and an L_{mincmy}.

In another embodiment, an apparatus for transforming a CMY color space gamut into a CMYK color space gamut comprises a processing unit, a memory unit coupled to the processing unit, and a software means operative on the processing unit. The software means is operative on the processing unit for obtaining an CIELAB space gamut from a first CMY space gamut. The CIELAB space gamut has a plurality of values and each of the plurality of values has a lightness component. After obtaining a CIELAB space gamut from a first CMY space gamut, the software means is operative for expanding the CIELAB space gamut by changing the lightness component of at least one of the plurality

of values of the CIELAB space gamut and transforming the CIELAB space gamut into the CMYK space gamut.

In another embodiment, a computer-readable medium has computer-executable instructions for performing a method. The method comprises first obtaining a CIELAB space gamut having a lightness component. The CIELAB space gamut is obtained from a CMYK space gamut which is obtained from a CMY space gamut. Second, the method comprises expanding the CIELAB space gamut by linearly rescaling the lightness component in the CIELAB space gamut using an L_{min}, an L_{max}, and an L_{mincmy}. Finally, the method comprises transforming the CIELAB space gamut into a second CMYK space gamut.

Brief Description of the Drawings

Figure 1 is a flow diagram of example embodiments of a method for black generation using lightness scaling.

Figure 2 is a diagram and a visualization of the lightness rescaling process in the CIELAB space.

Figure 3 is a projection for a color inkjet printer gamut surface.

Figure 4 is a diagram of alternate example embodiments of a method for increasing the use of a color gamut.

Figure 5 is a high level diagram of one embodiment of the inverse modeling process shown in Figure 4.

Figure 6 is a block diagram of example embodiments of an apparatus for transforming a CMY color space gamut into a CMYK color space gamut.

Figure 7 is a diagram of one embodiment of a computer readable media including computer executable instructions.

Detailed Description of the Invention

The present invention provides a method for relating a three-dimensional CMY coordinate system to CMYK colorant amounts in a way that increases the utilization of a printer gamut volume. A printer gamut, in one embodiment, is an arbitrary set of colors.

In general, adding a black colorant to any combination of CMY colorants does not result in a color with more chroma. Therefore, a CMYK gamut can be obtained from a CMY gamut by expanding the CMY gamut towards lower lightness values. Use of black colorant on the gray axis is enforced by modifying the initial distribution of CMY points through an approximate black generation transform. Lightness values of a resulting set of points in CIELAB space are scaled to fill the four-color gamut volume. The CMYK values corresponding to the modified CIELAB colors are found by inverting a printer model. This last process determines a specific black use rate which can depend on the region of the color space.

Figure 1 is a flow diagram of one embodiment of method 100 for black generation using lightness scaling. Black generation method 100 converts a CMY color space to a CMYK color space and includes black approximation process 103 for converting the CMY color space to a $CMYK_1$ color space. Black approximation process 103 is followed by forward model process 106 for converting the $CMYK_1$ color space to a CIELAB color space. The CIELAB color space is converted by lightness scaling process 109 to a Lab_1 color space. Finally, inverse model process 112 converts the Lab_1 color space to a CMYK color space.

In black approximation process 103, an approximate conversion from a CMY color space to a $CMYK_1$ color space is performed. Colors corresponding to output values generated by this conversion are within the original CMY gamut chroma boundaries. In addition, color values corresponding to the upper surface of the printer gamut are left unmodified, i.e.:

$$C_1 = C,\ M_1 = M,\ Y_1 = Y,\ K_1 = 0,\ \text{if } \min(C, M, Y) = 0 \text{ and } K = 0.$$

In one embodiment of black approximation process 103, a K=0 component is added. In an alternate embodiment, to impose a condition that balanced CMY values be converted to black:

$$C_1 = M_1 = Y_1 = 0,\ K_1 = C,\ \text{if } C = M = Y.$$

All the above conditions are satisfied by a black generation method known as achromatic reproduction, which is obtained from Equation (1) when $BG(x) = x$ and $UCR(x) = x$.

$$K_1 = \min(C, M, Y)$$
$$C_1 = C - K_1$$
$$M_1 = M - K_1$$
$$Y_1 = Y - K_1.$$

The final a^* and b^* coordinates of colors on ramps from black to primary and secondary colors are also implicitly defined in black approximation 103. By using nonlinear modifications of the above formula, desired colorant behavior can be obtained.

In one embodiment of forward model process 106, CIELAB values corresponding to the $CMYK_1$ values are obtained by printing and measuring a set of patches on a printer. In an alternate embodiment, CIELAB values are obtained from the $CMYK_1$ values by processing the $CMYK_1$ values using a printer model. A printer model is flexible and avoids the time and expense required to print and remeasure the patches when the black function is changed. A number of different techniques can be used for implementing a printer model. For example, a printer mode can be implemented as Neugebauer equations, lookup tables with interpolation, neural networks, fuzzy logic, or a polynomial regression.

In lightness rescaling process 109, the CIELAB point distribution is modified by changing the lightness components in such a way that the upper surfaces of the CMY gamut are preserved and the lower surfaces are mapped to the bottom surface of the full CMYK gamut. For each point obtained in forward model process 106, three corresponding points with identical a^* and b^* coordinates are identified. One of the points is located on the top surface of the CMYK gamut, which is identical to the top surface of the CMY gamut. The lightness of this point is denoted by L^*_{max}. The other two points are located on the bottom surfaces of the CMY and CMYK gamuts and have lightness L^*_{mincmy} and L^*_{min}, respectively. If black is not the darkest point in the gamut, to avoid non-monotonic behavior in some regions of the transform, the values of L^*_{min} can be

clipped to not less than L^* of black. In one embodiment, the modified L^* values are found by expanding the lightness range by linear rescaling:

$$L_1^* = \begin{cases} L_{\min}^* + (L^* - L_{mincmy}^*)\,(L_{\max}^* - L_{\min}^*) / (L_{\max}^* - L_{mincmy}^*) & \text{if } L_{\max}^* - L_{mincmy}^* \neq 0 \\ L^* & \text{otherwise.} \end{cases}$$

A diagram and visualization of the lightness rescaling process is shown in Figure 2.

In one embodiment of the present invention, a geometric method is used to determine the L^*_{min}, L^*_{max} and L^*_{mincmy} values. In an alternate embodiment, a constrained optimization method is used to determine the L^*_{min}, L^*_{max} and L^*_{mincmy} values. Neither of these embodiments is based on assumptions about the way CMY sub-gamuts for different values of K overlap and work in the presence of natural gamut boundaries.

The geometric method uses alpha shapes to determine the description of the gamut boundaries in the form of surfaces composed of triangles. The intersections of the lines of constant (a^*, b^*) with the top surface of the CMYK gamut and the bottom surfaces of CMYK and CMY gamuts are found. A search for triangles which are intersected by this line is performed after the L^* coordinates are ignored by projecting all the triangles onto the a^*b^* plane. Figure 3 shows such a projection for a color inkjet printer gamut surface. The solid and dashed lines correspond to the top and bottom gamut surfaces, respectively. Planar barycentric coordinates of a point (a^*, b^*) with respect to a triangle $P_1P_2P_3$ where $P_i = (L_i^*, a_i^*, b_i^*)$ are given by:

$$u = [(a^*_2 - a^*)\,(b^*_3 - b^*) - (a^*_3 - a^*)\,(b^*_2 - b^*)] / A$$
$$v = [(a^*_3 - a^*)\,(b^*_1 - b^*) - (a^*_1 - a^*)\,(b^*_3 - b^*)] / A$$
$$w = [(a^*_1 - a^*)\,(b^*_2 - b^*) - (a^*_2 - a^*)\,(b^*_1 - b^*)] / A$$

where A is the area of the triangle under consideration:

$$A = (a^*_2 - a^*_1)\,(b^*_3 - b^*_1) - (a^*_3 - a^*_1)\,(b^*_2 - b^*_1).$$

The line of constant (a^*, b^*) intersects a triangle if each of the coordinates (u, v, w) is greater than or equal to zero. Assuming that the gamut shape is sufficiently regular, for each (a^*, b^*) within the gamut chroma limits there will be two triangles like that: one on the top and one of the bottom surface of the gamut. The L^* value for each of the intersection points is then computed from the weighted sum:

$$L^* = uL_1 + vL_2 + wL_3.$$

Most printing processes impose a limit on the total Area Coverage (TAC), defined as the sum of the fractional areas covered by the halftone dots in the four separations. Exceeding the TAC limit is avoided by using only the points with colorant amounts less than TAC for computation of gamut surfaces.

The constrained optimization method is adapted for the purpose of finding the maximum and minimum L^* values on the gamut surface by searching for the point in the gamut which is the closest to the point outside the gamut which has the same a^* and b^* coordinates. The color space error function is constructed by weighting the a^* and b^* (or chroma and hue) much more strongly than lightness, for example, by setting $S_C = S_H = 1$ and $S_L = 0.001$. This produces the type of gamut mapping which transforms out-of-gamut points approximately vertically to points on the gamut surface. The range of lightness values is limited by the total area coverage (TAC) constraint incorporated in the optimization process.

For inverse model process 112, the expanded CIELAB values are inverted. The inversion process is subject to specific constraints. One constraint is based on the desired relationship between K and CMY. A second constraint is based on the Total Area Coverage (TAC) limit. The TAC constraint allows the black use rate to vary with the region of the color space to which the inversion is being applied.

After the CMYK values are obtained by inverse model process 112, the CMYK values can be smoothed. One useful smoothing kernel is based on a Laplace equation, which in the one-dimensional case (for the edges) is:

$$u_j = \frac{1}{2}(u_{j-1} + u_{j+1}) \quad \text{for } j = 1,\ldots, J-1 ,$$

where J is the number of grid points. In one embodiment, the smoothing process includes three operations. First, CMYK values for edges of the input CMY cube are smoothed, while keeping the corner values fixed. Second, the cube faces of the CMY cube are smoothed, while keeping the edges fixed. Finally, the whole cube volume is smoothed. Alternatively, smoothing can be performed by fitting a global model to the set of CMYK values and then using the fitted global model to obtain new values.

Figure 2 is a diagram and a visualization of the lightness rescaling process in the CIELAB space. Dashed line 203 shows the bottom of the CMY gamut. Line segments 206 and 209 show the intermediate outline of the gamut after approximate black generation. Line segments 212 and 215 show an outline of the full CMYK gamut. Vertical dashed line 218 has constant a^* and b^* coordinates. Point P_1 is not modified because it is on the upper surface of the gamut. Point P_2 is mapped from the bottom of the modified CMY gamut to a point P_3 on the bottom of the CMYK gamut. Point P_4 is inside the CMY gamut and is transformed to a point P_5 which has proportionally rescaled lightness.

Figure 4 is a diagram of alternate example embodiments of method 400 for increasing the use of a color gamut. The diagram includes first color space gamut 403, second color space gamut 406, third color space gamut 409, black generation 412, gamut distortion 415, forward mapping 416, linear rescaling 418, inverse modeling 419, modified gamut 421, and second gamut 424. The diagram also includes conversion paths 427, 430, 433, 436, and 439.

In one embodiment, first color space gamut 403 is a CMY color space gamut, second color space gamut 406 is a CMYK color space gamut, and third color space gamut 409 is a CIELAB gamut. In one embodiment of method 400, conversion path 427 employs black generation 412 in converting first color space gamut 403 to second color space gamut 406. In an alternate embodiment, conversion path 430 employs geometric

distortion 415 in the process of converting first color space gamut 403 to second color space gamut 406.

After converting first color space gamut 403 to second color space gamut 406, conversion path 433 employs forward mapping 416 to convert second color space gamut 406 to third color space gamut 409. In one embodiment, forward mapping 416 includes printing color patches from second color space 406 and performing a spectral analysis of the patches. The spectral analysis provides values in third color space gamut 409 into which the values of second color space gamut 406 may be mapped. In an alternate embodiment, forward mapping 416 includes developing and employing a model to map second color space 406 to third color space 409.

After converting second color space gamut 406 to third color space gamut 409, conversion path 436 employs linear rescaling 418 to convert third color space gamut 409 to modified gamut 421.

Finally, after converting third color space gamut 409 to modified gamut 421, conversion path 439 employs inverse modeling 419 to convert modified gamut 421 to second gamut 424.

Figure 5 is a high level diagram of one embodiment of inverse modeling 419 shown in Figure 4. A forward model *f(x)* 503 for mapping a control space 506, such as a CMYK color space, to a target space 509, such as a CIELAB color space is developed. An inverse model *g(x)* 512 for mapping the target space to the control space is derived from the forward model and various constraints. This method permits the specification of constraints on the desired relationship between K and CMY and on the Total Area Coverage (TAC) limit. This conversion process also produces second gamut 424 from modified gamut 421 as shown in Figure 4.

Figure 6 is a block diagram of example embodiments of apparatus 600 operable for transforming a CMY space gamut into a CMYK space gamut. Apparatus 600 includes processing unit 603, software means 606, storage unit 609, and image forming unit 612. Processing unit 603 is coupled to storage unit 609 and image forming unit 612. Software means 606 is operative on processing unit 603. Color image 615 is an input to processing unit 603.

Processing unit 603 is not limited to a particular type of information processor. Processing units suitable for use in connection with the present invention include microprocessors, mainframe processors, mid-range processors, reduced instruction set processors, complex instruction set processor, parallel processors, and massively parallel processors.

Storage unit 609 is not limited to a particular type of storage unit. In one embodiment, storage unit 609 is a solid state memory. Alternatively, storage unit 609 is a magnetic memory. In still another alternate embodiment, storage unit 609 is an optical memory.

Image forming unit 612 is not limited to a particular type of image forming unit. In one embodiment, image forming unit 612 is a color image forming unit, such as a color ink jet printer, a color laser printer, or an offset printing system. Alternatively, image forming unit 612 is a display device, such as a CRT, a plasma display, or a liquid crystal display. In still another alternate embodiment, image forming unit 612 is an image capture device, such as a color scanner.

Software means 606, in one embodiment, performs the operations of method 100 for black generation using lightness scaling shown in the flow diagram of Figure 1.

Figure 7 is an illustration of one embodiment of computer-readable medium 700 including computer executable instructions 703. Computer readable medium 700 includes any media capable of storing information, such as magnetic media, optical media, or electronic semiconductor media. Computer executable instructions 703 include instructions for expanding a color gamut, such as could be coded based on the method shown in Figure 1.

A method and apparatus for expanding a color gamut has been described. The method includes a series of conversions and transformations between color space gamuts which result in expanding and transforming an original color space gamut in such a way that a control space gamut, such as a CMYK space gamut, is more completely utilized.

Although specific embodiments have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that any arrangement which is calculated to achieve the same purpose may be substituted for the specific embodiment

shown. This application is intended to cover any adaptations or variations of the present invention. Therefore, it is intended that this invention be limited only by the claims and the equivalents thereof.

patent application

What is claimed is:

1. A method comprising:

converting a gamut in a first color space to a gamut in a second color space;

converting the gamut in the second color space to a gamut in a third color space;

rescaling a lightness component of a gamut value in the third color space to form a modified gamut; and

converting the modified gamut to a second gamut in the second color space.

2. The method of claim 1, wherein rescaling a lightness component of a gamut value in the third color space to form a modified gamut comprises:

modifying the gamut in the third color space by changing a lightness component of a color value in the third color space such that an upper surface of the gamut in the first color space is preserved and a lower surface of the gamut in the first color space is mapped to a bottom surface of the gamut of the second color space to form an expanded gamut in the third color space.

3. The method of claim 2, wherein converting a gamut in a first color space to a gamut in a second color space comprises:

applying a black generation method to the gamut in the first color space to form the gamut in the second color space.

4. A method comprising:

converting a gamut in a CMY color space having an upper surface and a lower surface to a gamut in a CMYK color space having a bottom surface;

converting the gamut in the CMYK color space to a gamut in a CIELAB color space, the gamut in the CIELAB color space having a lightness component;

modifying the gamut in the CIELAB color space by changing the lightness component such that the upper surface of the gamut in the CMY color space is preserved and the lower surface in the CMY color space is mapped to the bottom surface of the

gamut of the CMYK color space to form a gamut in an expanded CIELAB color space; and

transforming the gamut in the expanded CIELAB color space to form a second gamut in the CMYK color space.

5. The method of claim 4, wherein converting a gamut in a CMY color space having an upper surface and a lower surface to a gamut in a CMYK color space having a bottom surface comprises:

applying a black generation method to the gamut in the first color space to form the second gamut in the CMYK color space.

6. The method of claim 5, wherein applying a black generation method to the gamut in the first color space to form the second gamut in the CMYK color space comprises:

applying Gray Component Replacement (GCR) to the first gamut in the first color space to form the gamut in the second color space.

7. A method comprising:

modifying a CIELAB gamut having an L* component to form a modified CIELAB gamut; and

converting the modified CIELAB gamut to a color control space gamut subject to K constraints and TAC constraints.

8. The method of claim 7, wherein modifying the CIELAB gamut having an L* component to form a modified CIELAB gamut comprises:

linearly rescaling the L* component of the CIELAB gamut to form the modified CIELAB gamut.

9. The method of claim 7, wherein converting the modified CIELAB gamut to a color control space gamut subject to K constraints and TAC constraints comprises:

generating an inverse function of a forward function, the forward function is capable of mapping the color control space gamut to the modified CIELAB gamut and the inverse function is capable of mapping the modified CIELAB gamut to the control color space gamut.

10. A method comprising:

obtaining a CIELAB space gamut from a CMY space gamut;

changing a lightness component of the CIELAB space gamut to form an enhanced CIELAB space gamut; and

transforming the enhanced CIELAB space gamut to form a CMYK space gamut.

11. The method of claim 10, wherein obtaining a CIELAB space gamut from a CMY space gamut comprises:

transforming the CMY space gamut to obtain a CMYK space gamut by including a black colorant in the CMY space gamut; and

transforming the CMYK space gamut to form the enhanced CIELAB space gamut by printing a plurality of patches and measuring each of the plurality of patches to obtain the enhanced CIELAB space gamut.

12. The method of claim 10, wherein obtaining a CIELAB space gamut from a CMY space gamut comprises:

transforming a CMY space gamut to a CMYK space gamut by including a black colorant in the CMY space gamut to form the CMYK space gamut; and

transforming the CMYK space gamut into a CIELAB space gamut by computing the CIELAB space gamut from a model capable of mapping the CMYK space gamut into the CIELAB space gamut.

13. A method comprising:

obtaining a CIELAB space gamut from a CMYK space gamut obtained from a CMY space gamut;

expanding the CIELAB space gamut by changing the lightness component of the CIELAB space gamut; and

transforming the CIELAB space gamut into a second CMYK space gamut.

14. The method of claim 13, wherein changing the lightness component of the CIELAB space gamut comprises:

linearly rescaling the lightness component of the CIELAB space gamut.

15. The method of claim 14, wherein linearly rescaling the lightness component in the CIELAB space comprises:

computing a rescaling factor that is a function of an L_{min}, an L_{max}, and an L_{mincmy}.

16. Apparatus for transforming a CMY space gamut into a CMYK space gamut comprising:

a processing unit;

a memory unit coupled to the processing unit; and

software means operative on the processing unit for:

obtaining a CIELAB space gamut from a first CMY space gamut, the CIELAB space gamut having a plurality of values and each of the plurality of values having a lightness component;

expanding the CIELAB space gamut by changing the lightness component of at least one of the plurality of values of the CIELAB space gamut; and

transforming the CIELAB space gamut into the CMYK space gamut.

17. The apparatus of claim 16, wherein the processing unit is a microprocessor.

18. The apparatus of claim 16, further comprising:

an imaging unit coupled to the processing unit and capable of receiving the CMYK gamut and rendering an image from the CMYK gamut.

19. The apparatus of claim 16, wherein the memory unit is a semiconductor memory.

20. A computer-readable medium having computer-executable instructions for performing a method comprising:

obtaining a CIELAB space gamut having a lightness component, the CIELAB space gamut is obtained from a CMYK space gamut which is obtained from a CMY space gamut;

expanding the CIELAB space gamut by linearly rescaling the lightness component in the CIELAB space gamut using an L_{min}, an L_{max}, and an L_{mincmy}; and

transforming the CIELAB space gamut into a second CMYK space gamut.

21. The computer-readable medium of claim 20, further comprising:

transmitting the second CMYK space gamut to an imaging unit.

Abstract of the Disclosure

A color gamut in a first color space is expanded to utilize a larger gamut in a second color space. The gamut in the first color space is first converted by black generation or geometric distortion to a gamut in a second color space. The gamut in the second color space is converted by forward mapping to a gamut in a third color. The gamut in the third color space is expanded by linear rescaling. Finally, the linearly rescaled gamut is mapped to a gamut in the second color space through inverse modeling to form a final color gamut. The final color gamut utilizes the gamut available in the second color space, which is larger than the gamut available in the first color space.

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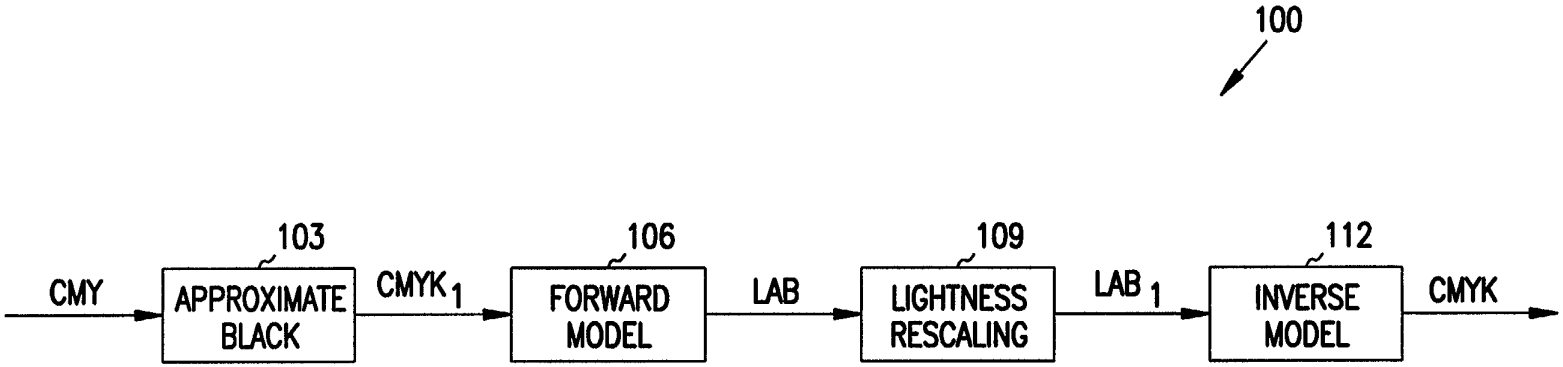

Figure 1

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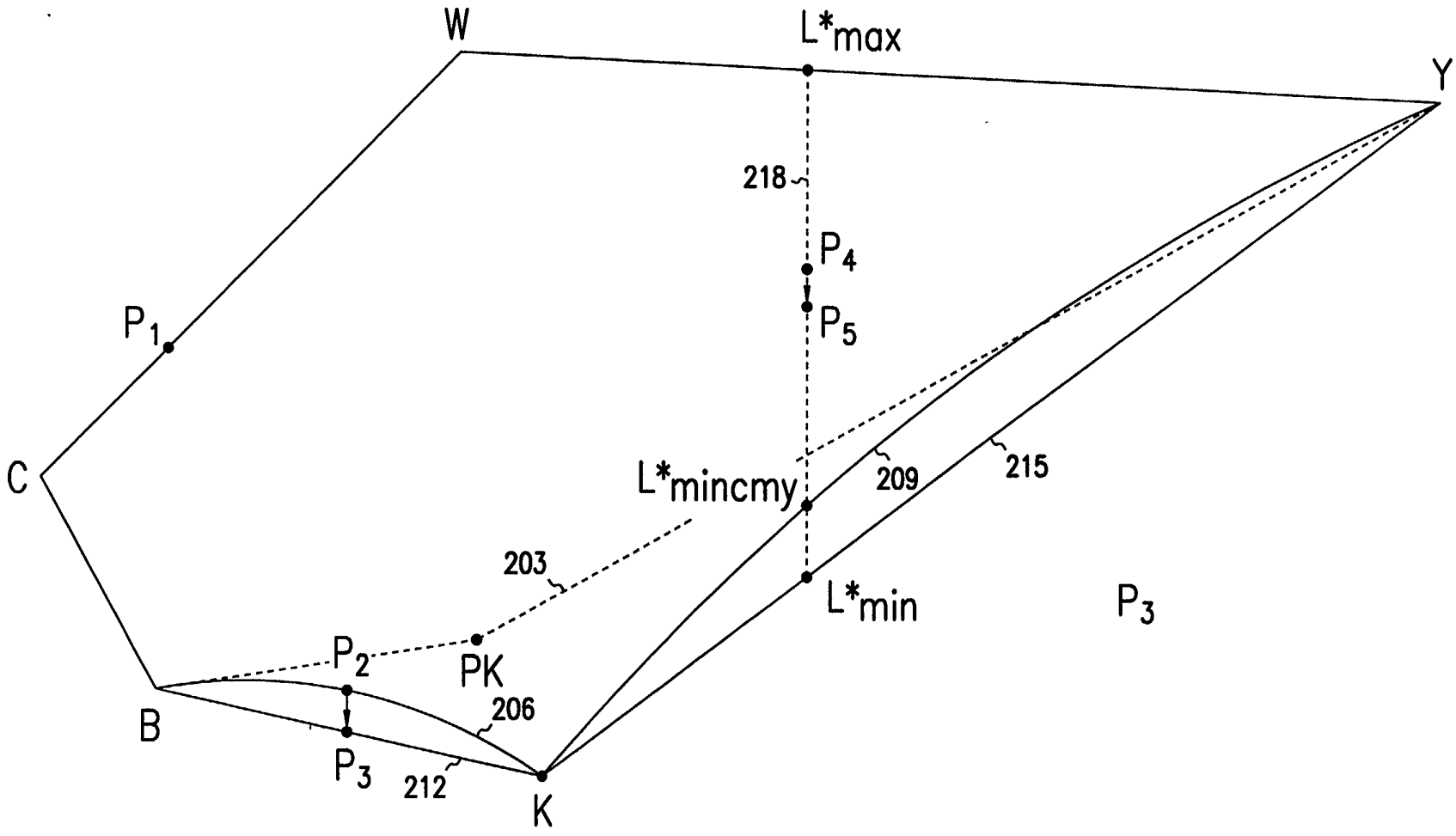

Figure 2

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patent search

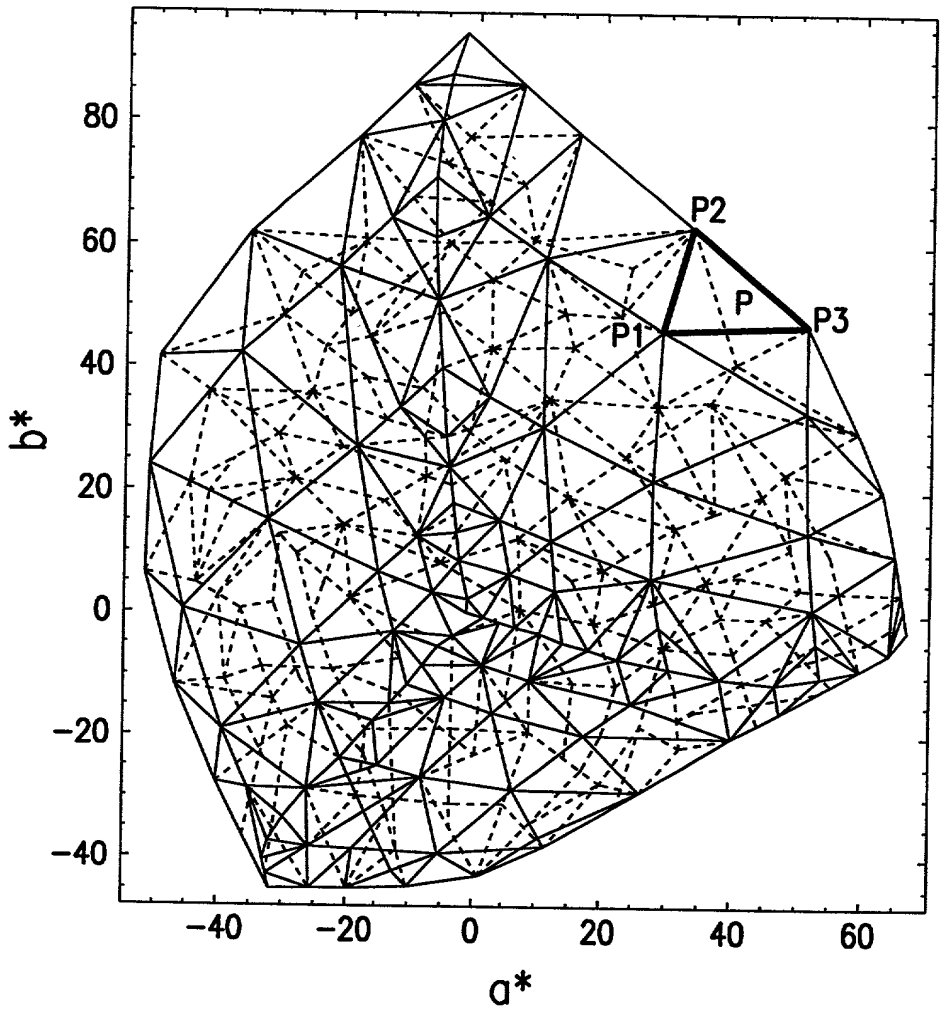

Figure 3

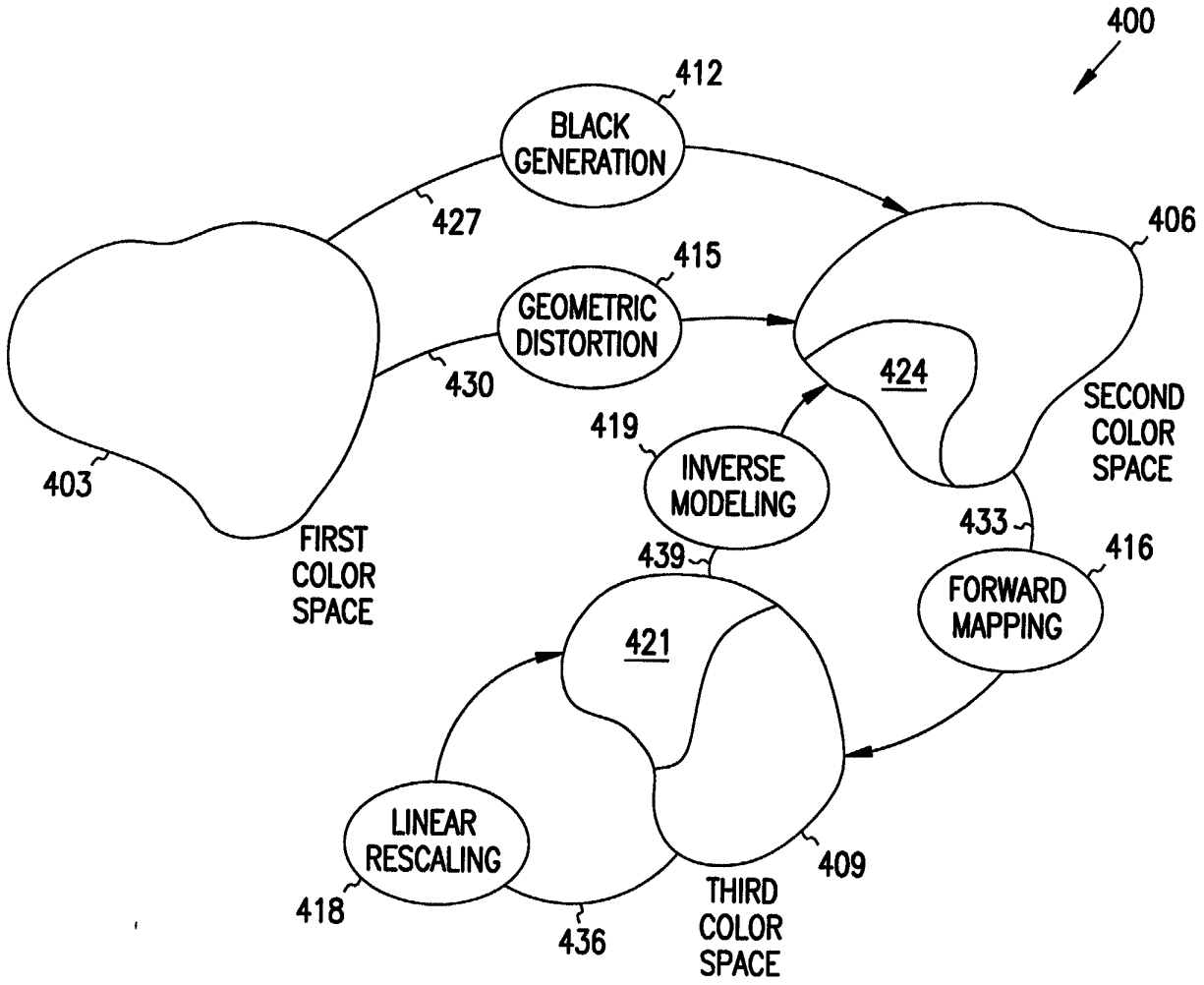

Figure 4

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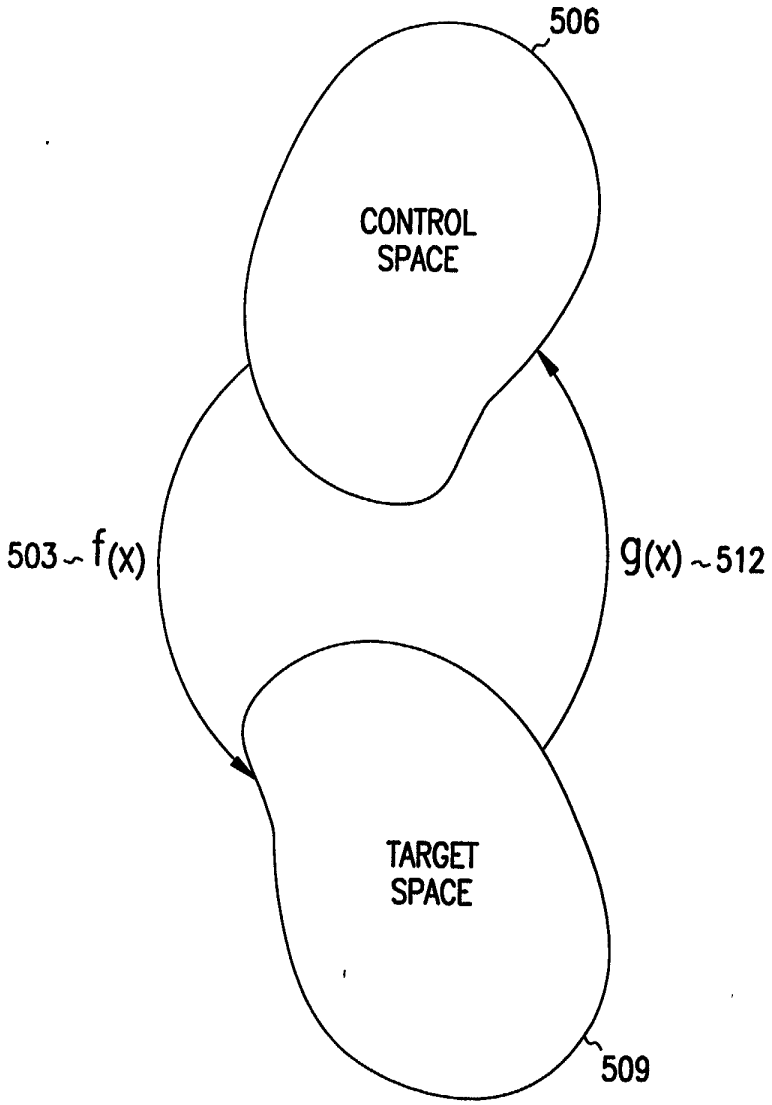

Figure 5

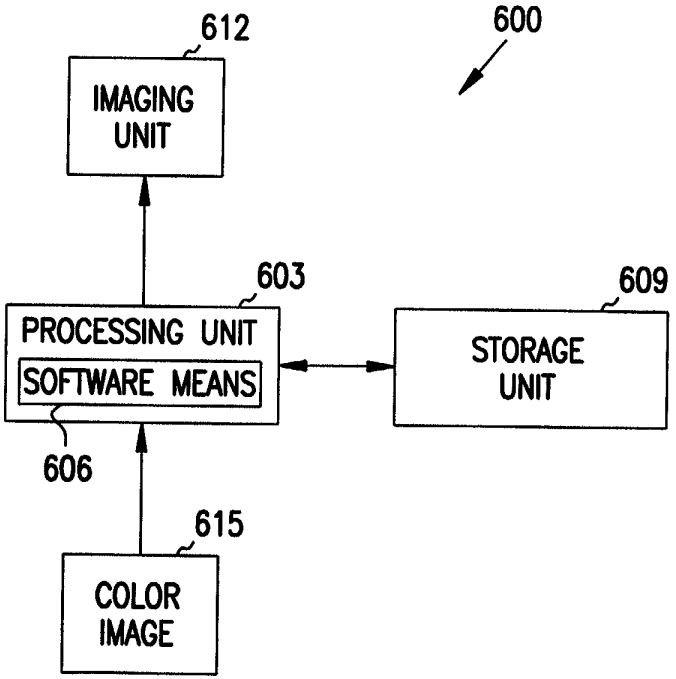

Figure 6

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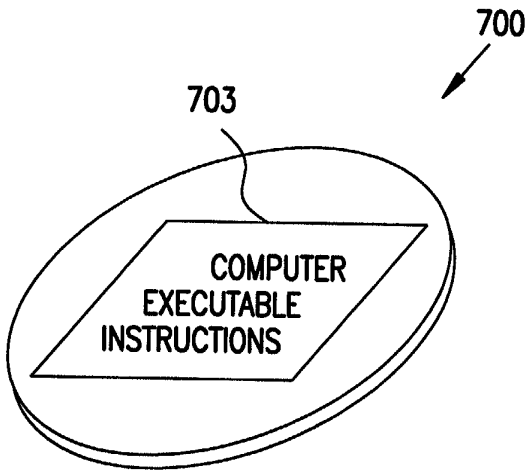

Figure 7

09489226 .012100

DECLARATION FOR PATENT APPLICATION

As a below named inventor I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name;

I believe I am an original, first an joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled:

METHOD AND APPARATUS FOR EXPANDING A COLOR GAMUT .

The specification of which is attached hereto.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose all information which is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, § 1.56 (see page 3 attached hereto).

I hereby claim foreign priority benefits under Title 35, United States Code, §119/365 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on the basis of which priority is claimed:

No such claim for priority is being made at this time.

I hereby claim the benefit under 35 U.S.C. § 119(e) of any United States provisional application(s) listed below:

No such claim for priority is being made at this time.

I hereby claim the benefit under Title 35, United States Code, § 120/365 of any United States and PCT international application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, § 1.56(a) which became available between the filing date of the prior application and the national or PCT international filing date of this application.

No such claim for priority is being made at this time.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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Tomasz J. Cholewo

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Signature: _____ Date: _____
Raymond E. Clark

Full Name of inventor:
Citizenship: Residence:
Post Office Address:

Signature: _____ Date: _____

Full Name of inventor:
Citizenship: Residence:
Post Office Address:

Signature: _____ Date: _____

§ 1.56 Duty to disclose information material to patentability.

(a) A patent by its very nature is affected with a public interest. The public interest is best served, and the most effective patent examination occurs when, at the time an application is being examined, the Office is aware of and evaluates the teachings of all information material to patentability. Each individual associated with the filing and prosecution of a patent application has a duty of candor and good faith in dealing with the Office, which includes a duty to disclose to the Office all information known to that individual to be material to patentability as defined in this section. The duty to disclose information exists with respect to each pending claim until the claim is canceled or withdrawn from consideration, or the application becomes abandoned. Information material to the patentability of a claim that is canceled or withdrawn from consideration need not be submitted if the information is not material to the patentability of any claim remaining under consideration in the application. There is no duty to submit information which is not material to the patentability of any existing claim. The duty to disclose all information known to be material to patentability is deemed to be satisfied if all information known to be material to patentability of any claim issued in a patent was cited by the Office or submitted to the Office in the manner prescribed by §§ 1.97(b)-(d) and 1.98. However, no patent will be granted on an application in connection with which fraud on the Office was practiced or attempted or the duty of disclosure was violated through bad faith or intentional misconduct. The Office encourages applicants to carefully examine:

(1) prior art cited in search reports of a foreign patent office in a counterpart application, and

(2) the closest information over which individuals associated with the filing or prosecution of a patent application believe any pending claim patentably defines, to make sure that any material information contained therein is disclosed to the Office.

(b) Under this section, information is material to patentability when it is not cumulative to information already of record or being made of record in the application, and

(1) it establishes, by itself or in combination with other information, a prima facie case of unpatentability of a claim; or

(2) it refutes, or is inconsistent with, a position the applicant takes in:

(i) opposing an argument of unpatentability relied on by the Office, or

(ii) asserting an argument of patentability.

A prima facie case of unpatentability is established when the information compels a conclusion that a claim is unpatentable under the preponderance of evidence, burden-of-proof standard, giving each term in the claim its broadest reasonable construction consistent with the specification, and before any consideration is given to evidence which may be submitted in an attempt to establish a contrary conclusion of patentability.

(c) Individuals associated with the filing or prosecution of a patent application within the meaning of this section are:

(1) Each inventor named in the application:

(2) Each attorney or agent who prepares or prosecutes the application; and

(3) Every other person who is substantively involved in the preparation or prosecution of the application and who is associated with the inventor, with the assignee or with anyone to whom there is an obligation to assign the application.

(d) Individuals other than the attorney, agent or inventor may comply with this section by disclosing information to the attorney, agent, or inventor.